

Technical Progress Report

Grant: NAG5-1858

**University of California, San Diego
9500 Gilman Drive, La Jolla CA 92093-0111**

**"Guaranteed Time Observations Support for
Goddard High Resolution Spectrograph (GHRS) on HST"**

Ed Beaver, Principal Investigator

Reporting PeriodZ: June 1, 1991 -- November 14, 1995

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I. Overall Progress

A. Results Obtained During the Reporting Period

1. GTO Observations

The goals of the GTO effort are for investigations defined in previous years by the IDT to be carried out as HST observations and for the results to be communicated to the scientific community and to the public. The following is a listing of GHRS GTO observations in the report period.

Scheduled and completed, with acceptable data:

Yr.day	Prop	Cy	Old #	Title	Target
91.194	1190	1	1190	FUV Em Line profiles, W Serpenteis Binaries	W Ser (1/1)
92.257	1191	2	1191	Phys Cond, Low z Abs Line Sys in QSOs	PKS2135-14 (1/3)*
94.163	5177	4	1191	Phys Cond, Low z Abs Line Sys in QSOs	PG1630+337 (2/3)
95.083	5698	4	1191	Phys Cond, Low z Abs Line Sys in QSOs	PG1630+337 (2/3)
95.071	6237	5	1191	Phys Cond, Low z Abs Line Sys in QSOs	PG0935 (3/3)
92.007	1192	1	1192	UV Emission Line Profiles, QSOs & AGN	OX169 (1/1)
91.338	1193	1	1193	Ly α Region of QSOs w Strong Absorp Lines	3C286 (1/3)
91.338	1193	1	1193	Ly α Region of QSOs w Strong Absorp Lines	PKS1229-02 (2/3)
92.359	3939	2	1193	Ly α Region of QSOs w Strong Absorp Lines	PKS1229-02 (2/3)
94.094	5176	4	1193	Ly α Region of QSOs w Strong Absorp Lines	PKS1229-02 Im (2/3)
91.339	1193	1	1193	Ly α Region of QSOs w Strong Absorp Lines	3C196 (3/3)
92.270	3939	2	1193	Ly α Region of QSOs w Strong Absorp Lines	3C196 (3/3)
94.083	5176	4	1193	Ly α Region of QSOs w Strong Absorp Lines	3C196 Image (3/3)

*Note: the (1/3) indicates this is the first of 3 targets in this program.

2. Publications (including partial support)

a) Papers Published or In Press

Rosenblatt, E. I, Beaver, E. A., Cohen, R. D., Linsky, J. B., and Lyons, R. W. 1991, "Cerenkov Background Radiation in Imaging Detectors", in *SPIE Electron Image Tubes and Image Intensifiers*, ed. Csorba, (Bellingham, WA) 1449, 72

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- Beaver, E. A., Baity, W. A., Brandt, J. C., Ebbets, D. C., Garner, H., Heap, S. R., Lindler, D. J., Linsky, J. B., Lyons, R. W., Rosenblatt, E. I. 1992, "Orbital Performance of the Goddard High Resolution Spectrograph Digicon Detectors on the Hubble Space Telescope", *Photoelectronic Image Devices 1991*, ed. B. L. Morgan, 65.
- Beaver, E. A., Cohen, R. D., Diplas, A., Garner, H., Heap, S. R., Loveland, M., and Robinson, R. D. 1993, "Calibration of GHRS Burst Noise Rejection Techniques", *Calibrating Hubble Space Telescope*, (Proceedings of a Workshop held at ST ScI, Nov. 1993), eds. J. C. Blades and S. J. Osmer, [Baltimore: Space Telescope Science Institute], 304.
- Linsky, J. L., Brown, A., Gayley, K., Diplas, A., Savage, B. D., Ayres, T. R., Landsman, W., Shore, S. N., and Heap, S. R. 1993, "GHRS Observations of the Local Interstellar Medium and the Deuterium/Hydrogen Ratio Along the Line of Sight Towards Capella", *Ap. J.*, **402**, 694.
- Brandt, J. C., Heap, S. R., Beaver, E. A., Boggess, A., Carpenter, K. G., Ebbets, D. C., Hutchings, J. B., Jura, M., Leckrone, D. S., Linsky, J. L., Maran, S. P., Savage, B. D., Smith, A. M., Trafton, L. M., Walter, F. M., Weymann, R. J., Snow, M., Randall, C. E., Lindler, D. J., Shore, S. N., Morris, S. L., Gilliland, R. L., Lu, L., and Robinson, R. D. 1993, "Observations of 3C 273 with the Goddard High Resolution Spectrograph on the Hubble Space Telescope", *AJ*, **105**, 831.
- Brandt, J. C., Heap, S. R., Beaver, E. A., Boggess, A., Carpenter, K. G., Ebbets, D. C., Hutchings, J. B., Jura, M., Leckrone, D. S., Linsky, J. L., Maran, S. P., Savage, B. D., Smith, A. M., Trafton, L. M., Walter, F. M., Weymann, R. J., Ake, T. B., Bruhweiler, F., Cardelli, J. A., Lindler, D. J., Malumuth, E., Randall, C. E., Robinson, R., Shore, S. N., Wahlgren, G. 1994, "The Goddard High Resolution Spectrograph: Instrument, Goals, and Science Results", *P.A.S.P.*, **106**, 890.
- Heap, S. R., Brandt, J. C., Randall, C. E., Carpenter, K. G., Leckrone, D. S., Maran, S. P., Smith, A. M., Beaver, E. A., Boggess, A., Ebbets, D. C., Garner, H. W., Hutchings, J. B., and Jura, M., *et al.* "The Goddard High Resolution Spectrograph: In-Orbit Performance", 1995, *P.A.S.P.*, **107**, 871
- Diplas, A., Beaver, E. A., Blanco, P. R. Piña, R. K. and Puetter, R. C., 1994, "Application of the Pixon Based Restoration to HST Spectra and Comparison to the Richardson-Lucy and Jansson Algorithms: Restoration of Absorption Lines", in *"The Restoration of HST Images and Spectra II"*, eds. R. J. Hanish and R.L. White (Baltimore, Md.: Space Telescope Institute Publications), 272.
- Diplas, A. and Savage, B. D., 1994 "An IUE Survey of Interstellar H I Ly α Absorption. I. Column Densities", *Ap. J.* **427**, 274.
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- Cohen, R. D., Barlow, T. A., Beaver, E. A., Junkkarinen, V. T., Lyons, R. W., Smith, H. E., 1994, "Conditions in the $z=0.692$ Absorber Towards 3CR 286", *Ap. J.*, 1994, **421**, 453-457.
- Burbidge, E. M., Beaver, E. A., Barlow, T. A., Cohen, R. D., Diplas, A., Hamann, F., Junkkarinen, V. T., and Lyons, R. W. 1995, "Recent Results from the UCSD FOS and GHRS Team", Conference Proceedings, *ESO Workshop on QSO Absorption Lines*, ed. Georges Meylan (Germany : ESO), 201.
- Weiland, J. L., Shore, S. N., Beaver, E. A., Lyons, R. W., and Rosenblatt, E. I., 1995 "Goddard High-Resolution Spectrograph Observations of the Interacting Binary System W Serpentis", *Ap. J.*, **447**, 401.
- Linsky, J. L., Diplas, A., Wood, B., Brown, A., Ayres, T., and Savage, B. D. 1994, "Deuterium and the Local Interstellar Medium Properties for the Procyon and Capella Lines of Sight", *Ap. J.*, **451**, 335.

b) Conference Proceedings

Diplas, A., Tripp, T. M., Beaver, E. A., 1993 "Observations of High Velocity Gas with HST/FOS and IUE," presented at the *ST Scl Halos Workshop*, Baltimore, MD.

Diplas, A., Beaver, E. A., Blanco, P. R., 1993 "Application of the Pixon Based Restoration to HST Spectra and Comparison to the Richardson-Lucy and Jansson Algorithms--Restoration of Absorption Lines", presented at the *HST Image Restoration Workshop*, Baltimore, Maryland.

Linsky, J. L., Diplas, A., Savage, B. D., Andrusis, C., and Brown, A. 1993, "Deuterium in the Local Interstellar medium", in *"Frontiers of Space and Ground-based Astronomy"*, ESTEC Workshop, Noordwijk, Netherlands.

Linsky, J. L., Diplas, A., Ayres, T., Wood, B., Brown, A. and Savage, B. D. 1994, "Hubble Observations of D/H in the Local ISM and Consequences for Cosmology", in *"Light Element Abundances"*, ESO/EIPC Workshop, Elba, Italy.

c) Abstracts and Invited Talks

Abstracts for 179th AAS Meeting, Atlanta, Georgia, January 1992

Lyons, R. W., Beaver, E. A., Rosenblatt, E. I., Weiland, J. L., "Spectroscopic Observations of the W Serpentis Binary System with the HST High Resolution Spectrograph", *B.A.A.S.*, **23**, 1415 (1991).

Abstracts for 180th AAS Meeting, Columbus, Ohio, June 1992

Beaver, E. A., Cohen, R. D., Junkkarinen, V. T., "Damped Lyman Alpha Absorption in 3CR 286", *B.A.A.S.*, **24**, 806 (1992).

Abstracts for 182nd AAS Meeting, Berkeley, California, June 1993

Diplas, A., Beaver, E. A., Cohen, R. D., Junkkarinen, V. T., and Lyons, R. W., "HST/FOS UV and Optical Observations of the QSO OX 169", *B.A.A.S.* **25**, 792, (1993).

Abstracts for the 183rd AAS Meeting, Washington, D.C., January 1994

Linsky, J. L., Diplas, A., Ayres, T., Wood, B., and Brown, A. 1994, "A Reanalysis of the Interstellar Medium Along the Capella Line of Sight", *B.A.A.S.*, **25**, 1464.

Abstracts for the 184th AAS Meeting, Minneapolis, MN, May-June 1994

Diplas, A., Cohen, R. D., Barlow, T. A., Beaver, E. A., Junkkarinen, V. T., and Lyons, R. W., "HST/FOS UV and WFPC II Observations of 3CR 196", *B.A.A.S.*, 1994, **26**, No. 2, 959.

Abstracts for the 185th AAS Meeting, Tucson, AZ, January 1995

Beaver, E. A., Burbidge, E. M., Cohen, R. D., Diplas, A., Junkkarinen, V. T., Lyons, R. W., and Loveland, M., 1994 "Looking for the Sources of Damped Ly α Absorption Lines in QSO Spectra", *B.A.A.S.*, **26**, 1331.

Cohen, R. D., Beaver, E. A., Diplas, A., Junkkarinen, V. T., and Lyons, R. W. 1994, "Observations of the 21 cm Absorber PKS 1229-021", *B.A.A.S.*, **26**, 1330.

3. Public Outreach

Informing the public is also a part of our mission. GHRS GTO team members regularly give public information lectures. W. Baity is the host of and science consultant to a semi-monthly UCSD-TV series on astronomy and space science. In the area of public information, we include the following:

- a) GHRS GTO team members at UCSD gave public information lectures and furnished a display for the ASP "Universe '93" meeting in San Diego in July 1993.
- b) GHRS team members at UCSD have maintained informative pages on the World Wide Web since June, 1994, to communicate our results to scientific colleagues and to the public.
- c) Two team members (Cohen and Baity) addressed a 300- teacher training workshop at UCSD in June 1994.
- d) Ross Cohen, presented "HST Results: Update" in the Astronomy Public Lecture Series, Reuben H. Fleet Space Theater, San Diego on 4/26/95.
- e) W. Baity gave a public lecture on "How HST Results are Changing our View of the Universe" to two audiences at San Diego's Fleet Space Theater in November, 1995.

B. Scientific Significance of Selected GTO Results

1. Results from Investigation 1190: the W Serpentis Interacting Binary System

Spectroscopic observations of the interacting binary system **W Serpentis** were made at two different orbital phases with the GHRS. Differences in Si IV $\lambda\lambda$ 1393, 1403 emission-line strengths and profile shapes observed between the two phases suggest that a hot spot exists where the giant stellar companion has transferred mass to an accretion disk surrounding the mass-gaining component. Moreover, strong absorption features superposed on the Si IV emission lines indicate that the accretion disk is geometrically and optically thick. These absorption features set constraints on models of the physical conditions of the disk.

2. Results from Investigation 1193: Ly α Region of 3 QSOs with Strong Absorption Lines

The damped Ly α systems at high redshifts have been suggested as the progenitors of normal galaxies. At moderate redshifts we can study these objects comprehensively with the HST. We have observed three quasars with 21 cm absorption and redshifts between 0.4 and 0.7 with the FOS and Wide Field Camera (WFC). As described below, the three objects show significantly different properties, rather than showing the similarities we might have suspected from their radio properties.

Observation of Ly α combined with 21 cm absorption yields the spin temperature, T_{c} , which may be indicative of the rate of energy input into the ISM. One goal of this work is to determine the rate of evolution of T_{c} . In 3CR286, $z_{\text{A}}=0.692$, we have found a spin temperature much higher than in the Galaxy and as high as in high-redshift objects. By comparing the column densities of metals measured in the optical with N(H I) measured in the UV, we have shown that the absolute abundances of Fe, Mg, and Ca in this object are very low. This is surprising, because we are seeing the ISM of this galaxy at a look-back time approximately equal to the age of the sun. Our WFC images do not clearly reveal the absorbing galaxy, suggesting that it may be a low surface brightness object and not a normal spiral galaxy.

In 3CR196, $z_{\text{A}}=0.437$, we have detected the probable site of the 21 cm absorption which occurs against the extended radio structure. It appears to be a normal barred spiral galaxy. The interpretation of the spectrum is complicated, but it appears the Ly α column density is high towards the optical QSO, several kiloparsecs away from the site of the 21 cm absorption. This suggests that the absorber is a normal spiral with a typical extended H I disk, and not a dwarf or a disturbed galaxy. In our spectrum of 3CR 196, we were also able to study an absorption system with approximately the same redshift as the emission lines. This absorption region appears to only partially cover the continuum source. We have found that the ionization is high, similar to that in Broad-Absorption-Line QSOs (BALQSOs). If the density is like the assumed density in BALQSOs, then the absorption region is close to the nuclear continuum source but outside the broad-line region.

The third object, **PKS 1229-021**, is being analyzed now. In this object, the absorber is a relatively low luminosity galaxy with a high Ly α column density and low spin temperature. However, the morphology of the

absorber is not obvious. We have detected [O II] emission from the nearby galaxies using observations with the Keck Telescope. From this we derive a star-formation rate of only a few solar masses per year. We can use this measurement (together with future work at high redshift) to derive the star formation history of the objects responsible for the damped Ly α and 21 cm systems.

II. Current Problems

None *per se*, but in order to complete detailed analysis of GHRS GTO data, we will likely need a no-cost extension beyond the end of the GTO support period in December 1996.

III. Plans for the Next Year of Support

The GHRS GTO at UCSD team has successfully completed the observation phase of their GTO investigations and for the next year will perform analyses of the observations listed in the first section above and complete work on previously obtained data. The HST has been performing up to its original design specifications, which is a testimonial to all those who worked hard on this project and its maintenance and repair.